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Re-examination of amino acids in Antarctic micrometeorites

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Abstract

The delivery of amino acids by micrometeorites to the early Earth during the period of heavy bombardment (4.5–3.5 Ga) could have been a significant source of the Earth's prebiotic organic inventory. Antarctic micrometeorites (AMMs) in the 100–200 μm size range represent the dominant mass fraction of extraterrestrial material accreted by the Earth today. However, one problem is that these 'large' micrometeorite grains can be heated to very high temperatures (1000 to 1500 °C) during atmospheric deceleration, causing the amino acids to decompose. In this study, we have analyzed the acid-hydrolyzed, hot water extracts from 455 AMMs for the presence of amino acids using high performance liquid chromatography. For comparison, a 5 mg sample of the CM meteorite Murchison was also investigated. In the Murchison sample we found high levels (~3–4 parts-per-million, ppm) of α-aminoisobutyric acid (AIB) and isovaline, two non-protein amino acids that are extremely rare on Earth and are characteristic of amino acids of apparent extraterrestrial origin. In contrast, we were unable to detect any AIB above the 0.1 ppm level in the AMM samples studied. Only in one AMM sample from a previous study has AIB been detected (~300 ppm). To date, more than 600 AMMs have been analyzed for extraterrestrial amino acids. Although our results indicate that less than 5% of all AMMs contain detectable levels of AIB, we cannot rule out the possibility that AIB can be delivered to the Earth intact by a small percentage of AMMs that escaped extensive heating during atmospheric entry.

Keywords: Amino acids; Micrometeorites; Prebiotic organic inventory

1. Introduction

Large micrometeorites ranging in size from 50 to 500 μm have been recovered from the Antarctic blue ice fields during the 1991 and 1994 field seasons. These meteorite grains represent the main source of extraterrestrial material that is accreted by the Earth each year (Chyba and Sagan, 1992; Love and Brownlee, 1993a). It has previously been shown that, Antarctic micrometeorites (AMMs) in the 100–200 μm size range correspond to the peak in the mass distribution of the micrometeorite flux (Kyte and Wasson, 1986; Maurette et al., 1991), estimated to be about 40 000 tons per year (Love and Brownlee, 1993a). In fact, the flux of 50–500 μm sized micrometeorites is 100 times more than objects found outside of this size range, including much larger meteorites and the smaller interplanetary dust particles (IDPs) collected in the stratosphere. AMMs have been found to be similar both petrologically and chemically to the CM type carbonaceous chondrites (Kurat et al., 1994). CM chondrites such as Murchison and Murray as well as several Antarctic meteorites are known to be rich in organic compounds, including amino acids (Kvenvolden et al., 1970; Kvenvolden et al., 1971; Cronin and Moore, 1971; Shimoyama et al., 1979, 1985). Over 70 different amino acids have now been identified in Murchison, most of them completely nonexistent in the terrestrial biosphere (Cronin and Chang, 1993). The α-dialkyl amino acids, α-aminoisobutyric acid (AIB) and isovaline, which are extremely rare amino acids on the

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